Remarks

Claims 11-15, 17-27 and 47-76 are pending in the Application.

Claims 11-15, 17-24, 27, 47-75 stand rejected.

Claims 25, 26 and 76 stand objected to.

Claims 24, 64 and 73 are currently amended.

Claims 77-86 are added herein.

I. 102(a)/103(a) REJECTIONS OVER *SHAFFER*

Examiner has rejected Claims 11, 15 and 47 under 35 U.S.C. § 102(a) as anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over Shaffer et al., *Advanced Materials*, 11, No. 11, 1999, pp. 937-941 ("*Shaffer*"). Office Action, at 3.

Regarding rejections under 35 U.S.C. § 102(a), anticipation requires each and every element of the claim to be found within the cited prior art reference. Regarding rejections under 35 U.S.C. § 103(a), to establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art and not based on applicant's disclosure. *See* M.P.E.P. 706.02(j); *see also In re Vaeck,* 947 F.2d 488, 20 U.S.P.Q.2d 1438 (Fed. Cir. 1991).

Shaffer teaches the use of multi-wall carbon nanotubes, as per the source (Hyperion Catalysis International, see *Shaffer*, footnote page 937) and per the statement: "It is not yet clear whether this result is chiefly a consequence of the imperfection in the graphite layers within the catalytically grown nanotubes used, or whether it relates to a fundamental difficulty of shear stress transfer between the shells of multi-wall carbon nanotubes" (*Shaffer*, page 939, col. 2, ll. 7-11). *See* also Baughman *et al.*, *Science*, **2002**, *297*, 787-792 ("*Baughman*") which states: "MWNTs produced

catalytically by gas-phase pyrolysis, like the Hyperion nanotubes..." (*Baughman*, page 788, col. 1, ll. 8-10).

Claims 11, 15, and 47 all require single-wall carbon nanotubes. As *Shaffer* does not teach single-wall carbon nanotubes, the rejection of these claims under 35 U.S.C. § 102(a) is improper.

Examiner states: "If it could be argued that arc-grown carbon nanotubes contain multi-wall nanotubes (MWNT) not single-wall nanotubes (SWNT), it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used the same method with the expectation of providing the desired covering of SWNT, since surface of SWNT is substantially identical to that of MWNT." Office Action, at 3. Applicant respectfully disagrees with this statement.

The distinction between single-wall and multi-wall carbon nanotubes is important because multi-wall carbon nanotubes are fundamentally different from single-wall carbon nanotubes.

Single-wall carbon nanotubes have only a single layer of sp^2-hybidized carbon atoms generally arranged in a hexagons and pentagons. Because of their single-layer, SWNT generally cannot support defects in growth and are more susceptible to destruction by bond breakage or reaction. In contrast, multi-wall carbon nanotubes are composed of multiple, cylindrical concentric carbon layers arranged in a nested fashion (analogous to Russian "nesting dolls"). Because of this arrangement, the carbon shells of multi-wall carbon nanotubes can withstand wall defects, which often appear as dislocations, kinks, holes, edges on the side-wall surfaces, *etc.* Also because of their multiple layers and the interconnections between these layers, multi-wall nanotubes can withstand much more rigorous chemical processing, physical conditions, and extensive chemical bond breakage without nanotube destruction compared to single-wall carbon nanotubes.

Single-wall carbon nanotubes "rope" together and are held tightly by van der Waals forces. As such, single-wall nanotubes are difficult to separate and disperse in other media, while multi-wall nanotubes generally do not rope and, as such, are readily separable and dispersible. The structural differences between single-wall and multi-wall carbon nanotubes also leads to differences in physical and chemical properties, such as tensile strength, modulus, flexibility, thermal conductivity, electrical conductivity, chemical reactivity and chemical stability.

As a result of such differences, the chemistry that can be done with each species is quite different and unpredictable. Thus, it would not have been obvious to one of ordinary skill in the art to apply the processes of *Shaffer* to that of single-wall carbon nanotubes.

Furthermore, there is no reasonable expectation of success in using the teachings of *Shaffer* with single-wall carbon nanotubes. The generally smaller size of single-wall carbon nanotubes compared to multi-wall carbon nanotubes, the roping of single-wall carbon nanotubes and the difficulty in dispersing single-wall carbon nanotubes due to their tendency to be held tightly together by van der Waals forces would discourage one of ordinary skill from expecting that the teachings of *Shaffer* would give a similar result or work with single-wall carbon nanotubes.

As *Shaffer* neither teaches nor suggests polymer-coated single-wall carbon nanotubes, Claim 11 and Claims 15, and 47, dependent on Claim 11, are neither anticipated, nor rendered obvious, by *Shaffer*.

Accordingly, Applicant respectfully requests that the Examiner withdraw the rejection of Claims 11, 15 and 47 under 35 U.S.C. § 102(a) as being anticipated by, or in the alternative, under 35 U.S.C. § 103(a) as being obvious over *Shaffer*.

II. 102(b)/103(a) REJECTIONS OVER *UCHIDA*

Examiner has rejected Claims 11, 15 and 17 under 35 U.S.C. § 102(b) as anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over Uchida et al., U.S. Patent 5,560,898 ("*Uchida*"). Office Action, at 3.

As in the case of *Shaffer* above, *Uchida* does not teach single-wall carbon nanotubes required by each of Claims 11, 15, and 17. Rather, *Uchida* teaches purification of multi-wall carbon nanotubes formed by the method of Ebbesen. *Uchida* states: "One method for the preparation of carbon nanotubes is disclosed by Ebbesen et al. (Nature, 358, 220(1992))." *Uchida*, col. 1, ll. 13-15. *Uchida* further states: "Such a raw material mixture may be obtained by the method disclosed in the above Ebbesen et al article." *Uchida*, col. 2, ll. 1-3. As *Uchida* does not teach single-wall carbon nanotubes, the rejection of Claims 11, 15 and 17 under 35 U.S.C. § 102(b) is improper.

Applicant respectfully traverses Examiner's assertion that, "If it could be argued that the carbon nanotubes of *Uchida* et al., contain only MWNT, it would have been obvious to one of

ordinary skill in the art at the time the invention was made to have used the same method with the expectation of providing the desired covering of SWNT, since surface of SWNT is substantially identical to that of MWNT." Office Action, at 3-4. As noted above, there are many properties of single-wall and multi-wall carbon nanotubes that are very different. In particular, the roping and tight associating of single-wall carbon nanotubes makes single-wall carbon nanotubes very difficult to separate and disperse. Thus, there is no reasonable expectation of success in using the teachings of *Uchida* with single-wall carbon nanotubes. The generally smaller size of single-wall carbon nanotubes compared to multi-wall carbon nanotubes, the roping of single-wall carbon nanotubes and the difficulty in dispersing single-wall carbon nanotubes due to their tendency to be held tightly together by van der Waals forces would discourage one of ordinary skill from expecting that the teachings of *Uchida* would give a similar result or work with single-wall carbon nanotubes

Thus, as in *Shaffer*, *Uchida* does not teach or suggest polymer-coated single-wall carbon nanotubes required by Claim 11 and Claims 15, and 17, dependent on Claim 11. As such, Claims 11, 15, and 17 are neither anticipated by, nor obvious in view of, *Uchida*.

Accordingly, Applicant respectfully requests that the Examiner withdraw rejection of Claims 11, 15 and 17 under 35 U.S.C. § 102(b) as being anticipated by, or in the alternative, under 35 U.S.C. § 103(a) as being obvious over *Uchida.*

III. 102(a)/103(a) REJECTIONS OVER *DAVEY*

Examiner has rejected Claims 11, 13, 15, 24 and 48 under 35 U.S.C. § 102(a) as anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over Davey et al., U.S. Patent 6,576,341 ("*Davey*"). Office Action, at 4.

Regarding Claims 11, 13, 15, 24 and 48, each of these claims requires single-wall carbon nanotubes. As in *Shaffer* and *Uchida* above, *Davey* does not teach single-wall carbon nanotubes required by each of Claims 11, 13, 15, 24 and 48. Rather, *Davey* teaches purification of multi-wall carbon nanotubes. As *Davey* does not teach single-wall carbon nanotubes, Claims 11, 13, 15, 24 and 48 cannot be held anticipated under 35 U.S.C. § 102(a).

Applicant respectfully traverses Examiner's assertion that, "If it could be argued that the carbon nanotubes of *Davey* et al., contain only MWNT, it would have been obvious to one of

ordinary skill in the art at the time the invention was made to have used the same method with the expectation of providing the desired covering of SWNT, since surface of SWNT is substantially identical to that of MWNT." Office Action, at 4. As noted above, there are many properties of single-wall and multi-wall carbon nanotubes that are very different. In particular, the roping and tight associating of single-wall carbon nanotubes makes single-wall carbon nanotubes very difficult to separate and disperse. Thus, there is no reasonable expectation of success in using the teachings of *Davey* with single-wall carbon nanotubes. The generally smaller size of single-wall carbon nanotubes compared to multi-wall carbon nanotubes, the roping of single-wall carbon nanotubes and the difficulty in dispersing single-wall carbon nanotubes due to their tendency to be held tightly together by van der Waals forces would discourage one of ordinary skill from expecting that the teachings of *Davey* would give a similar result or work with single-wall carbon nanotubes

Thus, as in *Shaffer* and *Uchida, Davey* does not teach or suggest polymer-coated single-wall carbon nanotubes required by Claims 11 and Claims 13, 15, 24 and 48, dependent on Claim 11. As such, Claims 11, 13, 15, 24 and 48 are neither anticipated by, nor obvious in view of, *Davey*.

Accordingly, Applicant respectfully requests that the Examiner withdraw the rejection of Claims 11, 13, 15, 24 and 48 under 35 U.S.C. § 102(a) as being anticipated by, or in the alternative, under 35 U.S.C. § 103(a) as being obvious over *Davey*.

IV. 103(a) REJECTIONS OVER *KUPER* IN VIEW OF *SHAFFER*

Examiner has rejected Claims 11, 12, 14, 15, 18, 19 and 47 under 35 U.S.C. § 103(a) as obvious over Kuper, U.S. Patent Application, Publication No. US 2002/0092613 A1 ("*Kuper*") in view of *Shaffer*. Office Action, at 4.

Applicant respectfully points out that *Kuper* was filed August 23, 2001—the same day that the present Application was filed. As such, *Kuper* is not a valid prior art reference; thus, these rejections are improper and must be withdrawn.

Applicant further notes that *Kuper* claims priority to United States Provisional Patent Application Serial Number 60/227,184, filed on August 23, 2000 (the "*Kuper* Provisional Patent Application," which is attached hereto at Exhibit A). The *Kuper* Provisional Patent Application predates the two provisional patent applications to which Applicant claims priority, namely, United

States Provisional Patent Application No. 60/227,604, filed on August 24, 2000, and from United States Provisional Patent Application No. 60/268,269, filed on February 13, 2001 (collectively, the "Applicant Provisional Patent Applications").[1] However, unlike Applicant's Provisional Patent Applications, which do disclose polymer coating of nanotubes, no such disclosure is found anywhere in the *Kuper* Provisional Patent Application.

Kuper included the following two sentences, which concluded the first paragraph in the Detailed Description:

> For purposes of this disclosure, "chemical treatment" or "chemically treated" can include functionalization, (covalent attachment of organic functional groups), adherence of a surfactant molecule or wrapping of a polymer around the body of the tube. The sol gel process, as defined in this patent will include a sol of chemically treated SWNTs using the definition of definition of chemical treatment above.

Kuper, pg. 3, para. 27. This is the only mention in *Kuper* respecting surfactants, the adherence of a surfactant molecule to a nanotube, and the wrapping of a polymer around the body of a nanotube. *Id.* In fact, the terms "surfactant" and "wrapping" are not used anywhere else in *Kuper* other than in these two sentences.

A review of the *Kuper* Provisional Patent Application reflects that these two sentences from *Kuper* (quoted above) were new matter added in *Kuper*. *See* Kuper Provisional Patent Application, at 9 as compared with *Kuper*, pg. 3, para. 27. A further review of the *Kuper* Provisional Patent Application reveals that there is no such disclosure anywhere within.

Accordingly, such new matter is not prior art to the present application. *See* M.P.E.P. § 2136.03(IV).

The relevance of this is due to the Examiner's specific reliance upon the above quoted language in support of the rejections. Office Action, at 4. In fact, this new matter is the cornerstone of the Examiner's arguments that the invention would have been obvious over *Kuper* in view of *Shaffer*. *Id.*, at 4-6.

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[1] Applicant notes that the *Kuper* Provisional Patent Application was filed one day before the first of the two filed Applicant Provisional Patent Applications. As noted *infra*, the *Kuper* Provisional Patent Application is not material to the present Application. Nonetheless, if the Examiner decides to cite the *Kuper* Provisional Patent Application as prior art, Applicant notes that it intends to swear behind this reference. Accordingly, Applicants respectfully asserts that is not waiving its rights to swear behind this reference and reserve the right to do so at the appropriate time.

Accordingly, Applicant respectfully requests that the Examiner withdraw the rejection of Claims 11, 12, 14, 15, 18, 19 and 47 under 35 U.S.C. § 103(a) as being obvious over *Kuper* in view of *Shaffer*.

V. 103(a) REJECTION OVER *SHAFFER/KUPER* IN VIEW OF *SHAFFER* IN VIEW OF *RIGGS-JPCB*

Examiner has rejected Claim 17 under 35 U.S.C. § 103(a) as obvious over *Shaffer/Kuper* in view of *Shaffer*, in view of Riggs et al., *J. Phys. Chem. B* 2000, 104, pp. 7071-7076 (*"Riggs-JPCB"*). Office Action, at 6.

As above, Applicant respectfully points out that *Kuper* is not a valid prior art reference. Thus, the rejection over *Kuper* in view of *Shaffer* in view of *Riggs-JPCB* must be withdrawn.

As to Examiner's alternative rejection of *Shaffer* in view of *Riggs-JPCB* regarding Claim 17, this claim depends directly from Claim 11, which was differentiated from *Shaffer* above. *Riggs-JPCB* teaches, *inter alia*, the suspension of single-wall carbon nanotubes in aqueous solutions using Triton X-100 surfactant. The method of *Riggs-JPCB* can be used to suspend ropes of single-wall carbon nanotubes, but is not effective in separating the nanotubes and overcoming the strong van der Waals attractive forces that hold the single-wall carbon nanotube ropes tightly together. *See* Rinzler *et al.*, *Appl. Phys. A*, **1998**, *67*, 29-37. Thus, the combination of *Riggs-JPCB* and *Shaffer* would not result in the polymer-coated single-wall carbon nanotubes required by Claim 17.

Furthermore, there is no suggestion or motivation in either *Shaffer* or *Riggs-JPCB* to modify either reference to obtain the present claimed invention. Therefore, Claim 17 cannot be obvious over *Shaffer* in view of *Riggs-JPCB*.

Accordingly, Applicant respectfully requests that the Examiner withdraw rejection of Claim 17 under 35 U.S.C. § 103(a) as being obvious over *Shaffer/Kuper* in view of *Shaffer*, in view of *Riggs-JPCB*.

VI. 102(b) REJECTIONS OVER *RIGGS-JACS*

Examiner has rejected Claims 20 and 22 under 35 U.S.C. § 102(b) as anticipated by Riggs et al., *J. Am. Chem. Soc.* 2000, 122, pp 5879-5880 (*"Riggs-JACS"*). Office Action, at 7.

Examiner contends that *Riggs-JACS* discloses "a method for making polymer-coated carbon nanotubes comprising mixing (functionalized) single-wall nanotubes (SWNT) and polypropionylethyleneimine-co-ethyleneimine in a solvent and reacting at 165°C for 20 min." Office Action, at 7.

Regarding Claims 20 and 22, Applicant respectfully traverses the rejection. Anticipation requires each and every element of the claim to be found within the cited prior art reference.

Riggs-JACS does not teach or suggest a polymer-coated carbon nanotube. Rather, *Riggs-JACS* teaches polymers covalently bonded to the ends of carbon nanotubes. *Riggs-JACS* states: "According to the STM results, it appears that the polymer attachment is at the end of nanotube..." *See Riggs-JACS*, page 5879, col. 1, para. 2. *Riggs-JACS* derivatized (functionalized) the nanotubes with acyl chloride groups which were subsequently reacted with the imine copolymer and/or poly(vinyl acetate-co-vinyl alcohol) in order to covalently bond the copolymer to the nanotube. *See Riggs-JACS*, page 5879, col. 1, para. 2.

In contrast, the invention requires polymer-coated single-wall carbon nanotubes, which are not covalently bonded as stated in the Application: "The polymer that covers these small ropes and tubes attaches to the SWNTs through weak chemical forces that are primarily non-covalent in nature." *See* Application, page 7, ll. 17-19. As such, *Riggs-JACS* teaches away from the present invention. Therefore, Claims 20 and 22 cannot be anticipated by *Riggs-JACS*.

Accordingly, Applicant respectfully requests that the Examiner withdraw the rejection of Claims 20 and 22 under 35 U.S.C. § 102(b) as being anticipated by *Riggs-JACS*.

VII. 103(a) REJECTIONS OVER *SHAFFER* IN VIEW OF *TOHJI*

Examiner has rejected Claims 20-23, 49-54, 66 and 75 under 35 U.S.C. § 103(a) as obvious over *Shaffer* in view of Tohji et al., *Fullerene Sci. and Tech.*, 7(4), pp. 665-679, 1999, ("*Tohji*"). Office Action, at 7.

Regarding Claims 20-23, 49-54, 66 and 75, these claims all require polymer-coated single-wall carbon nanotubes. Neither *Shaffer* nor *Tohji*, either alone or in combination, teaches a method of preparing polymer-coated single-wall carbon nanotubes.

As above, *Shaffer* teaches suspensions of multi-wall carbon nanotubes for preparing composite materials. *Tohji* teaches a method (HIDE treatment) for purifying single-wall carbon nanotube soot by 1) heating in water at 373°K for 12 hours; 2) drying at 333°K for 12 hours; 3) Soxhlet extracted with toluene to remove fullerenes; 4) heating in air at 743°K for 20 minutes to burn out amorphous carbon particles; and 5) eliminating the metal complexes using 6N hydrochloric acid.

Neither *Shaffer* nor *Tohji* provides suggestion or motivation for one of ordinary skill in the art to combine these teachings to obtain the present claims. Furthermore, *Tohji* actually teaches away from a combination in acknowledging the difficulties in drawing analogies between single-wall carbon nanotubes and multi-wall carbon nanotubes by stating: "Various purification methods proposed for multi-walled carbon nanotubes (MWNTs) have been applied to SWNTs, however, there is no report of their success." *Tohji*, page 671, para. 3.

Accordingly, Applicant respectfully requests that the Examiner withdraw rejection of Claims 20-23, 49-54, 66 and 75 under 35 U.S.C. § 103(a) as obvious over *Shaffer* in view of *Tohji.*

VIII. 103(a) REJECTIONS OVER *DAVEY* IN VIEW OF *TOHJI*

Examiner has rejected Claims 20-23, 49-54, 60-64, 67, 68, and 71-73 under 35 U.S.C. § 103(a) as obvious over *Davey* in view of *Tohji*. Office Action, at 8.

Regarding Claims 20-23, 49-54, 60-64, 67, 68, and 71-73, all of these claims are directed to methods of making polymer-coated single-wall carbon nanotubes. As there is no suggestion or motivation in either *Davey* or *Tohji* to make such species, these claims cannot be held obvious under 35 U.S.C. § 103(a).

As stated above, *Davey* is directed to a method for purifying multi-wall carbon nanotubes by extraction with an organic material having a "coiling" structure. Such a process differs substantially from the process for purifying single-wall carbon nanotubes of *Tohji* which employs a number of steps, none of which uses an organic material with a "coiling" structure.

Neither *Davey* nor *Tohji* provides suggestion or motivation for one of ordinary skill in the art to combine these teachings. Furthermore, as stated above, *Tohji* actually teaches away from a combination in acknowledging the difficulties in drawing analogies between single-wall carbon nanotubes and multi-wall carbon nanotubes by stating: "Various purification methods proposed for

multi-walled carbon nanotubes (MWNTs) have been applied to SWNTs, however, there is no report of their success." *Tohji*, page 671, para. 3.

Furthermore, even if the teachings of the references were combined, the combination would not produce all the limitations involving polymer-coated single-wall carbon nanotubes required by Claims 20-23, 49-54, 60-64, 67, 68, and 71-73. As such, Claims 20-23, 49-54, 60-64, 67, 68, and 71-73 cannot be held as obvious over *Davey* in view of *Tohji*.

Accordingly, Applicant respectfully requests that the Examiner withdraw rejection of Claims 20-23, 49-54, 60-64, 67, 68, and 71-73 under 35 U.S.C. § 103(a) as obvious over *Davey* in view of *Tohji*.

IX. 103(a) REJECTIONS OVER *RIGGS-JACS*

Examiner has rejected Claims 21 and 23 under 35 U.S.C. § 103(a) as obvious over *Riggs-JACS*. Office Action, at 9.

Regarding Claims 21 and 23, these claims are dependent on Claim 20, which claims a method for making polymer-coated single-wall carbon nanotubes. The polymer in the present claims "attaches to the single-wall carbon nanotubes through weak chemical forces that are primarily non-covalent in nature." *See* Application, page 7, ll. 17-19. In contrast, and as mentioned above, *Riggs-JACS* teaches carbon nanotubes with polymers covalently bonded to the ends of carbon nanotubes. *Riggs-JACS* does not contain all the elements of the present claims for making polymer-coated single-wall carbon nanotubes and actually *teaches away* from such methods by teaching the covalent functionalization and bonding at the nanotube ends. As there is no motivation or suggestion in *Riggs-JACS* to modify the reference to obtain the present claims, Claims 21 and 23 cannot be held obvious under 35 U.S.C. § 103(a) over *Riggs-JACS*.

Accordingly, Applicant respectfully requests that the Examiner withdraw rejection of Claims 21 and 23 under 35 U.S.C. § 103(a) as being obvious over *Riggs-JACS*.

X. 103(a) REJECTION OVER *SHAFFER/KUPER* IN VIEW OF *SHAFFER* IN VIEW OF *BOWER*

Examiner has rejected Claim 27 under 35 U.S.C. § 103(a) as obvious over *Shaffer/Kuper* in view of *Shaffer*, in view of Bower et al., EP 989579 (*"Bower"*) Office Action, at 9.

As noted above, *Kuper* is not prior art. Thus, the rejection over *Kuper* in view of *Shaffer* in view of *Bower* must be withdrawn.

As to Examiner's alternative rejection of *Shaffer* in view of *Bower*, Claim 27 is directed to the alignment of polymer-coated single-wall carbon nanotubes. Applicant respectfully asserts that neither *Shaffer* nor *Bower*, either alone or in combination, teaches polymer-coated single-wall carbon nanotubes. *Shaffer* teaches a suspension of multi-wall carbon nanotubes. *Bower* teaches a method of preparing aligned single-wall carbon nanotubes for field emission devices. *Bower* teaches a nanotube-polymer composite made by casting, molding or other techniques, then inducing alignment of the nanotubes by melting the polymer and "straining the composite with a uniaxial load." In *Bower*, the method of nanotube alignment is done when the polymer is in a melted state. *Bower* teaches alignment of the nanotubes using an electric field and a magnetic field during *in situ* growth of the nanotubes. In contrast, the present claim presents a method which requires, *inter alia,* that polymer-coated single-wall carbon nanotubes and polymer to be dispersed in a solvent and that the nanotubes are aligned by an electric field, magnetic field or shear flow field. There is no suggestion or motivation in *Shaffer* or *Bower* to modify either of the references to obtain the presently claimed invention.

Furthermore, even if the teachings of the references were combined, the combination would not produce all the limitations involving polymer-coated single-wall carbon nanotubes required by Claim 27. As such, Claim 27 cannot be held as obvious over *Shaffer* in view of *Bower*.

Accordingly, Applicant respectfully requests that the Examiner withdraw the rejection of Claim 27 under 35 U.S.C. § 103(a) as being obvious over *Shaffer/Kuper* in view of *Shaffer*, in view of *Bower*.

XI. 103(a) REJECTION OVER *SHAFFER/KUPER* IN VIEW OF *SHAFFER* IN VIEW OF *RIGGS-JPCB*, AND FURTHER IN VIEW OF *HSU*

Examiner has rejected Claim 55 under 35 U.S.C. § 103(a) as obvious over *Shaffer/Kuper* in view of *Shaffer*, in view of *Riggs-JPCB*, and further in view of Hsu U.S. Patent 5,653,996 (*"Hsu"*) Office Action, at 10.

As noted above, *Kuper* is not prior art. Thus the rejection over *Kuper* in view of *Shaffer* in view of *Riggs-JPCB* further in view of *Hsu* must be withdrawn.

Regarding Examiner's alternative rejection of *Shaffer* in view of *Riggs-JPCB* and further in view of *Hsu*, Claim 55, which is dependent on Claims 17 and 11, is a method which requires, *inter alia,* polymer-coated single-wall carbon nanotubes, wherein a polymer and the nanotubes are dispersed in a solvent, and the solvent comprises water and a surfactant, which is SDS. Applicant respectfully traverses the rejection.

As noted above, *Shaffer* teaches suspensions of multi-wall carbon nanotubes. *Riggs-JPC*B teaches, *inter alia*, the suspension of single-wall carbon nanotubes in aqueous solutions using Triton X-100 surfactant. *Hsu* teaches a method for preparing liposomes, wherein surfactants are used as "bilayer-forming materials." As noted above, these suspensions of nanotubes are distinct from the polymer-coated single-wall carbon nanotubes of the present invention. None of the references, *Shaffer*, *Riggs-JPCB*, *Hsu*, or any combination thereof, teach a method for making the polymer-coated single-wall carbon nanotubes as claimed by the present claimed invention. Moreover, none of the references provides any suggestion or motivation for combining the references to obtain the present claim. Such combination is also unlikely, given the number and dissimilar nature of the references.

Accordingly, Applicant respectfully requests that the Examiner withdraw the rejection of Claim 55 under 35 U.S.C. § 103(a) as being obvious over *Shaffer/Kuper* in view of *Shaffer*, in view of *Riggs-JPCB*, and further in view of *Hsu.*

XII. 103(a) REJECTIONS OVER *SHAFFER* IN VIEW OF *TOHJI* OR *DAVEY* IN VIEW *TOHJI*, IN VIEW OF *RIGGS-JPCB*

Examiner has rejected Claims 58 and 69 under 35 U.S.C. § 103(a) as obvious over *Shaffer* in view of *Tohji* or *Davey*, in view of *Tohji*, in view of *Riggs-JPCB*. Office Action, at 11.

Regarding Claims 58 and 69, these claims depend directly on Claims 20 and 22, respectively, and both are methods for making polymer-coated single-wall carbon nanotubes. As noted above, *Shaffer* teaches suspensions of multi-wall carbon nanotubes; *Davey* is directed to method of purifying multi-wall carbon nanotubes by extracting them with organic material having a "coiling" structure; *Tohji* teaches purification of single-wall carbon nanotubes using numerous steps involving water, Soxhlet extraction, and air oxidation, and *Riggs-JPCB* teaches suspension of single-wall carbon nanotubes in Triton X-100 solutions. In contrast, Claims 58 and 69 require, *inter alia*, a method for making polymer-coated single-wall carbon nanotubes.

None of the references, *Shaffer*, *Davey, Tohji*, *Riggs-JPCB*, or any combination thereof, teach a method for making the polymer-coated single-wall carbon nanotubes as required by Claims 58 and 69. Moreover, none of the references provides any suggestion or motivation for combining the references to obtain the present claims. Such combination is also unlikely, given the number and somewhat dissimilar nature of the references. As such, these claims cannot be held obvious under 35 U.S.C. § 103(a).

Accordingly, Applicant respectfully requests that the Examiner withdraw rejection of Claims 58 and 69 under 35 U.S.C. § 103(a) as obvious over *Shaffer* in view of *Tohji* or *Davey*, in view of *Tohji*, in view of *Riggs-JPCB*.

XIII. 103(a) REJECTIONS OVER *SHAFFER* IN VIEW OF *TOHJI* OR *DAVEY* IN VIEW *TOHJI*, IN VIEW OF *RIGGS-JPCB*, AND FURTHER IN VIEW OF *HSU*

Examiner has rejected Claims 59 and 70 under 35 U.S.C. § 103(a) as obvious over *Shaffer* in view of *Tohji* or *Davey*, in view of *Tohji*, in view of *Riggs-JPCB*, and further in view *Hsu*. Office Action, at 12.

Regarding Claims 59 and 70, these claims depend indirectly on Claims 20 and 22 respectively, both of which claim a method for making polymer-coated single-wall carbon nanotubes.

As noted above, *Shaffer* teaches suspensions of multi-wall carbon nanotubes; *Davey* is directed to method of purifying multi-wall carbon nanotubes by extracting them with organic material having a "coiling" structure; *Tohji* teaches purification of single-wall carbon nanotubes using numerous steps involving water, Soxhlet extraction, and air oxidation, *Riggs-JPCB* teaches suspension of single-wall carbon nanotubes in Triton X-100 solutions and *Hsu* teaches a method for preparing liposomes, wherein surfactants are used as "bilayer-forming materials." In contrast, Claims 59 and 70 require, *inter alia*, a method for making polymer-coated single-wall carbon nanotubes.

None of the references, *Shaffer*, *Davey, Tohji,* Riggs-*JPCB*, *Hsu* or any combination thereof, teach a method for making the polymer-coated single-wall carbon nanotubes as required by Claims 58 and 69. Moreover, none of the references provides any suggestion or motivation for combining the references to obtain the present claims. Such combination is also unlikely, given the number and dissimilar nature of the references. As such, these claims cannot be held obvious under 35 U.S.C. § 103(a).

Accordingly, Applicant respectfully requests that the Examiner withdraw rejection of Claims 59 and 70 under 35 U.S.C. § 103(a) as obvious over *Shaffer* in view of *Tohji* or *Davey*, in view of *Tohji*, in view of *Riggs-JPCB,* and further in view *Hsu.*

XIV. 103(a) REJECTIONS OVER *SHAFFER* IN VIEW OF TOHJI/DAVEY IN VIEW *TOHJI*, AND FURTHER IN VIEW OF *BOWER*

Examiner has rejected Claims 65 and 74 under 35 U.S.C. § 103(a) as obvious over *Shaffer* in view of *Tohji/Davey*, in view of *Tohji*, and further in view *Bower.* Office Action, at 12.

Regarding Claims 65 and 74, these claims depend directly on Claims 20 and 22, respectively, and claim a method for making polymer-coated single-wall carbon nanotubes.

As noted above, *Shaffer* teaches suspensions of multi-wall carbon nanotubes; *Davey* is directed to method for purifying multi-wall carbon nanotubes by extracting them with organic

material having a "coiling" structure; *Tohji* teaches purification of single-wall carbon nanotubes using numerous steps involving water, Soxhlet extraction, and air oxidation, and *Bower* teaches a method of preparing aligned single-wall carbon nanotubes for field emission devices. In contrast, Claims 65 and 74 require, *inter alia*, a method for making polymer-coated single-wall carbon nanotubes, wherein the nanotubes are aligned.

None of the references, *Shaffer*, *Davey, Tohji, Bower* or any combination thereof, teach a method for making the polymer-coated single-wall carbon nanotubes as claimed by the Claims 65 and 74. Moreover, none of the references provides any suggestion or motivation for combining the references to obtain the present claims. Such combination is also unlikely, given the number and dissimilar nature of the references. As such, these claims cannot be held obvious under 35 U.S.C. § 103(a).

Accordingly, Applicant respectfully requests that the Examiner withdraw rejection of Claims 65 and 74 under 35 U.S.C. § 103(a) as obvious over *Shaffer* in view of *Tohji/Davey*, in view of *Tohji*, and further in view *Bower*.

XV. ALLOWABLE SUBJECT MATTER

The Examiner indicated that Claims 25-26 and 76 were objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. Office Action, at 13.

Applicant respectfully submits that Claim 25, was amended and written in independent form to comply with Examiner's objections in the first Office Action of Oct. 3, 2003 (Paper 6). The amended claim was included in the Amendment under 37 C.F.R. § 1.111, filed on March 8, 2003 ("Prior 1.111 Amendment").

As to Claims 26 and 76, these claims depend from Claim 25, which was rewritten in independent form and submitted in the Prior 1.111 Amendment.

Accordingly, Applicant respectfully requests that the Examiner withdraw the objections of the Claims 25, 26 and 76.

XVI. ADDED CLAIMS

New Claims 77-86 are added herein.

Claims 77-85 depend directly or indirectly from Claims 11, 20, and 22, and therefore have all of the limitations of these claims, but further require the addition of a salt to effectively "promote coating of the polymer on the single-wall carbon nanotubes to form polymer-coated single-wall carbon nanotubes." No new matter is introduced by such amending. Support for such amending can be found in the specification. *See* Application page 16, para. 2, ll. 13-14; and page 18, para. 1, ll. 1-2.

XVII. CONCLUSION

As a result of the foregoing, it is asserted by Applicant that the Claims in the Application are now in a condition for allowance, and respectfully request an early allowance of such Claims.

Applicants respectfully request that the Examiner call Applicant's attorney at the below listed number if the Examiner believes that such a discussion would be helpful in resolving any remaining problems.

Respectfully submitted,

WINSTEAD SECHREST & MINICK P.C.

Attorneys for Applicant

By: _____

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08/23/00

Class	Subclass

ISSUE CLASSIFICATION

[redacted]

PROVISIONAL APPLICATION NUMBER

Form PTO-1625
(Rev. 6/99)

(FACE)

PATENT APPLICATION

60227184

Date Entered or Counted

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Bib Data Sheet

SERIAL NUMBER	FILING DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
60/227,184	08/23/2000 RULE _	–	–	65304-001

APPLICANTS
Cynthia A. Kuper, Philadelphia, PA ;

** CONTINUING DATA **********

** FOREIGN APPLICATIONS **********

** SMALL ENTITY **

Foreign Priority claimed	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ yes ☐ no	PA	2	–	–
35 USC 119 (a-d) conditions met ☐ yes ☐ no ☐ Met after Allowance				
Verified and Acknowledged Examiner's Signature Initials				

ADDRESS
–
25203

TITLE
Method for utilizing sol-gel processing in the production of a macroscopic two or three dimensionally ordered array of single wall nanotubes (SWNTS)

FILING FEE RECEIVED	FEES: Authority has been given in Paper	
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Cynthia A.	Kuper	1520 Spruce Street Apartment 703 Philadelphia, PA 19103

[ ] *Additional inventors are being named on the ___ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

Method for Utilizing Sol-Gel Processing in the Production of a Macroscopic Two or Three Dimensionally Ordered Array of Single Wall Nanotubes (SWNTS)

CORRESPONDENCE ADDRESS

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ENCLOSED APPLICATION PARTS *(check all that apply)*

[X]	Specification *Number of Pages* 13	[ ]	Small Entity Statement
[X]	Drawing(s) *Number of Sheets* 2	[ ]	Other (specify)

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

[ ] A check or money order is enclosed to cover the filing fees

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[ ] No.

[ ] Yes, the name of the U.S. Government agency and the Government contract number are: _____

Respectfully submitted,

SIGNATURE _____ Date 8/23/00

TYPED or PRINTED NAME Scott J. Fields

REGISTRATION NO. *(if appropriate)* 32,857

TELEPHONE 215-665-3214

Docket Number: 65304-001

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C., 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, D.C., 20231.

DOCKET NO. 65304-001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: Provisional Patent Application

Title: Method for Utilizing Sol-Gel Processing in the Production of a Macroscopic Two or Three Dimensionally Ordered Array of Single Wall nanotubes (SWNTs)

Inventor: Cynthia A. Kuper

CERTIFICATE OF EXPRESS MAIL UNDER 37 CFR 1.10

Assistant Commissioner for Patents
Box Provisional Application
Washington, DC 20231

"Express Mail" Mailing Label Number: EL092591006US

Date of Deposit: August 23, 2000

I hereby certify that this provisional patent application is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Assistant Commissioner for Patents, Box Provisional Application, Washington, DC 20231.

SCOTT J. FIELDS

Date: August 23, 2000

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271402

DOCKET 65304-001

Title

Method for utilizing sol-gel processing in the production of a macroscopic two or three dimensionally ordered array of single wall nanotubes (SWNTs).

Field of the Invention

The Invention relates to the field of materials science and materials fabrication comprising carbon nanotubes.

Background of the Invention

Carbon is a critical element of organic material, which makes up all living matter. Matter composed solely of carbon exists in the form of graphite, diamond and most recently the fullerenes. These forms are called allotropes and are chemically very stable. Allotropes of carbon can be used alone, or in combination with other materials to form composites, to make applicable materials such as industrial diamonds; for cutting tools and flat panel displays, carbon filaments; in the form of fibers for structural reinforcement and dielectrics, activated carbon; for filtration devices, electrode materials for the manufacturer of steel, construction materials; for insulation of nuclear reactors, and graphite rods; for high-temperature hearing elements.

With the discovery of the third allotrope of carbon, the fullerenes, carbon materials having a fine tubular structure within the order of a nanometer in diameter, have been discovered on a carbon rod after an arc discharge, a common way of producing carbon fullerenes (S. Iijima, Nature, Vol. 354, pp. 56-58, 7 Nov. 1991). These fibrilar carbon materials may be visualized by (a) providing benzene shell-like hexagonal molecules as a constituent unit which are formed by covalent bonding of carbon atoms,

(b) placing the molecules tightly in a plane to form a carbon molecule sheet, (c) rolling the carbon molecule sheet into a cylindrical shape to form a cylindrical carbon tube as a unit or a high-molecular building block, (d) repeating the above steps (a)-(c) to form a plurality of cylindrical carbon tubes having different diameters, and thereafter (e) arranging their cylindrical carbon tubes in a concentric configuration to form a telescopic structure.

The above-mentioned cylindrical tubes have an extreme micro-diameter of the order of 1 nm at a minimum, and the spacing between a cylindrical tube and its inside cylindrical tube or its outside cylindrical tube is of the order of 0.34 nm which is approximately the same as the interlayer spacing of a graphite molecule. The interaction between tubes is van der Waals type, and electron transfer from tube to tube is very small. In the above-mentioned telescopic structure, there are various kinds of structure such as a double structure, triple structure, quadruple structure, quintuple structure.

The above fibrilar carbon material will be hereinafter referred to in some cases as a "(carbon) nanotube" or a "(carbon) tube". Carbon nanotubes can take an almost infinite number of structures, which are characterized both by their diameter and their degree of helicity. The relation between the molecular structure and electronic band structure of the carbon nanotube has been taught in Japanese Patent Application No. 56306/1992 which was laid open on Sep. 7, 1993 under Japanese Unexamined Patent Publication No. 229809/1993, the disclosure of which is hereby incorporated by reference herein. In addition, a method of fabricating carbon tube devices having desired properties on the basis of the above relation has been proposed therein.

The above Application No. 56306/1992 and N. Hamada et al., Phys. Rev. Lett., 68(10), pp.1579-1581(1992) teach that the carbon nanotubes exhibit a variety of properties in electronic conduction from a metal to a semiconductor having various band gaps, depending on the radius of the cylindrical tube and the degree of helical arrangement of the six-membered carbon rings (i.e. the carbon hexagons), further, that the carbon nanotubes are useful as a material for use in functional devices utilizing such properties.

On the other hand, soccer ball-like spherical high-molecular weight carbon materials having benzene shell-like hexagonal molecules as a constituent unit or molecular building block are taught in S. Iijima et al., Nature, Vol. 356, pp. 776-778(1992). S. Iijima et al. have shown that a variety of complex variants of carbon nanotubes are obtained by introducing pentagons and heptagons into the hexagonal network. Also, it is known that the molecules such as C.60, C.70, C.78, C.82, can exist in a stable state. These soccer ball-like spherical carbon materials are in the solid state or in the form of a face-centered cubic lattice or any other crystal structures depending on van der Waals forces. If the crystal or solid material is doped with K, Rb, Cs or the like, the doped material exhibits the metal conduction and superconductivity at low temperature.

The above-mentioned carbon nanotube and soccer ball-like materials and high-molecular weight materials derived from either of them are thus well known. Carbon nanotubules have received a great attention as a new base material applicable to various industries. The teachings of U.S. Patent No. 5,457,343, for example, discloses the use of a carbon nanotubule as an absorbent or complex enclosure for foreign materials.

Graphite is a layered material and is structured with the carbon hexagons spread out two dimensionally and repeated forming layers of graphite sheets. The methods of making graphite carbon materials have been well established and are being used by industry for mass production of graphite. The methods of making normal graphite materials are divided into three main types. There is a method of forming graphite using a liquid-phase carbonization process with ground coke and a bonding material as raw materials. There is a method which uses a solid-phase carbonization process using spun polyacrylonitrile, pitch and rayon filaments as they are, and there is a method which thermally decomposes hydrocarbon gases and then performs a gas-phase carbonization process.

Of the carbon materials with graphite type structure, graphite filaments could have been obtained by using the solid-phase carbonization method mentioned above, or could have been formed by thermal decomposition of hydrocarbon gases using metallic granules as a catalyst, or could have been obtained by forming amorphous carbon filaments using metallic granules as a catalyst and then heat-treating these filaments to make graphite. Also, a method is known of where needle shaped graphite could have been grown by applying a direct current discharge between two graphite electrodes in a rare gas atmosphere.

For example, one of the prior methods of growing the graphite filaments was proposed in 1960 by Roger Bacon of Union Carbide Co. (U.S.A.) (J. Appl. Phys., Vol. 31, p. 283 (1960)), and in this method direct current is discharged between two carbon-rod electrodes in an argon gas atmosphere at approximately 90 atmospheres, forming graphite filaments with a diameter of 1 to 5 .mu.m and length of 2 to 3 cm on the

negative electrode. Using this method, the crystal structure of the resulting graphite filament is the same as that of normal graphite. In other words, each of the graphite filaments is structured with several oblong shaped single crystal graphite bundled around the filament axis, and each oblong graphite crystals bond together along the crystal boundaries to form a polycrystalline structure.

As mentioned above, the chemical and physical properties of carbon materials taking currently known graphitic structures as the main structural unit are well known. When considering more diverse industrial applications of carbon, a new carbon carbon-based material having a new structure is desired.

Carbon nanotubes have been refined so that they can be can be synthesized as single wall nanotubes (SWNTs.) SWNTs are micron long nanometer diameter tubes composed solely of carbon atoms. The geometrical arrangement of the carbon atoms in a SWNT is that of graphene (a single sheet of graphite). The overall configuration resembles a sheet of chicken wire, which is rolled to close seamlessly and capped with hemispheres on each end of the tube. In each vertice of the hypothetical chicken wire exists a carbon atom. This provides the graphene configuration. SWNTs are proposed to be 100 times stronger than steel at 1/6 the weight. SWNTs have the highest strength to weight ratio of any material known today. They can have conductivities of a metal or a small gap semiconductor, parallel to the tube axis. Perpendicular to the tube axis they are completely insulating and have thermal properties similar to diamond. These remarkable properties are entirely anisotropic and therefore rely on the SWNTs to be completely aligned with respect to one another.

While carbon nanotubes and SWNTs have been known, there has heretofore been no known way to produce an ordered array of SWNTs. The term "ordered array" defines a periodic architecture composed of SWNTs aligned with respect to one another in either a parallel or perpendicular configuration. Such a parallel configuration would have all the tubes aligned along the tube axis and would be considered a two dimensional array. A perpendicular configuration would have an alternating structure of every other tube aligned parallel to the tube axis with tubes in between lying perpendicular and would be considered a three dimensional array. These architectures would allow for the full exploitation of all the properties, electrical and mechanical, of a SWNT in bulk.

Such macroscopically aligned arrays of SWNTs produced via this methodology have applications towards structural reinforcement materials such as those in automobile panels, airplane fuselage structures, as well as maritime and aerospace technologies. Applications also include those for biotechnology such as use in synthetic membranes and skins. Fiber processing of SWNTs can also be achieved using this method.

The sol gel process is a known chemical protocol that involves initially a sol, a sub micron solid particle forming a colloidal suspension in a liquid, Secondly, an additive which gels the sol, usually a chemical that promotes condensation of more than one solid particle to itself, Thirdly: a heat treatment period which evaporates the liquid. The final result is a thin (<1um) or thick film (>1um) of a dimensionally ordered solid array.

Sol gel processing as described above is principally used in the ceramic industry. It is a well known and reliable method for making high temperature ceramic composites and ceramic films. It is a significant technique in that it allows one to process solid particles using wet chemistry. This lends control and precision in the development of the

final product. Insoluble particles are traditionally hard to process. Sol gel processing provides a powerful solution to these processing limits.

The use of sol gel processing, heretofore, has not been applied to SWNTs. SWNTs are not soluble in any liquid and this causes the material to have many processing limits. Sol Gel processing of SWNTs will over come these barriers and allow the material to be used for the many applications previously mentioned.

It is the fundamental purpose of the present invention to provide a method for fabricating two or three dimensionally order arrays of SWNTs using sol gel processing.

Summary of the Invention

In accordance with the present invention, a method for fabricating of macroscopic two or three dimensionally ordered arrays of single wall nanotubes (SWNTs) is disclosed. The first embodiment of the invention comprises the following steps: chemically treating purified SWNTs using known laboratory protocols, comprised of standard organic chemistry techniques, to add chemically reactive groups (functional groups) to either the tube ends or tube bodies in order to functionalize the SWNTs; applying the sol-gel process to these functionalized carbon nanotubes, which is comprised of the following steps; suspending the functionalized SWNTs in an appropriate liquid medium such that a colloid is produced; treating the colloid with a chemical or heat to promote coupling of the individual functionalized SWNTs to each other; and heating the coupled SWNTs to evaporate any excess liquid so as to provide a final product comprising an array of covalently bound functionalized SWNTs.

The second embodiment of the invention comprises a method for fabricating of macroscopic two or three dimensionally ordered arrays of single wall nanotubes

(SWNTs) comprising the following steps: chemically treating purified SWNTs using known laboratory protocols, comprised of standard organic chemistry techniques, to add chemically reactive groups comprising alcohols or amines to either the tube ends or tube bodies in order to functionalize the SWNTs; applying the sol-gel process to these functionalized carbon nanotubes, which is comprised of the following steps; suspending the functionalized SWNTs in an appropriate liquid medium such that a colloid is produced; treating the colloid with a chemical or heat to promote the covalent bonding of the individual functionalized SWNTs to each other; and heating the coupled SWNTs to evaporate any excess liquid so as to provide a final product comprising an array of covalently bound functionalized SWNTs.

The third embodiment of the invention comprises the steps in the first and/or second embodiment of the invention coupled with the use of shear stress (a uniaxial applied load) on the "gel"; the stage of sol-gel processing prior to evaporation of the entirety of the liquid, electric fields, and/or magnetic fields to further promote alignment of the carbon nanotubes in the gel stage.

The fourth embodiment of the invention is the inclusion of the first, second and/or third embodiments coupled with the addition of a second substance to the sol-gel processing. This substance can be a polymer, epoxy, resin or ceramic material such that introduction of a colloidal suspension of the second substance to the colloidal suspension of the functionalized carbon nanotubes, with subsequent sol-gel processing on the mixture, yield a composite system. This composite system may have both components substantially aligned with respect to one another in a two or three dimensional fashion.

Description of the Figures

Figure 1 is a flow diagram of the method of the present invention.

Detailed Description of the Invention

The present invention and method is now described as follows with reference to the attached flow diagram. In a most preferred embodiment, the present invention is directed to a method for using sol gel processing in the production of a macroscopic two or three dimensionally ordered array of carbon nanotubes, either of the multiwall or single wall variety. First, the purified carbon nanotubes are chemically treated using known laboratory protocols, comprised of standard organic chemistry techniques, to add chemically reactive groups to the tube ends and/or tubes body. The reactive groups may be, but are not limited to, primary alcohols and amines. This synthesis is performed using known methods for side wall (tube body) functionalization of the carbon nanotubes and may include further modifications to the synthesis.

The functionalized carbon nanotubes (carbon nanotubes with chemical groups attached) are then suspended in an appropriate liquid medium such that a colloid is produced, i.e., a stable suspension of individual functionalized SWNTs. This colloid will be treated with the addition of another chemical or by physical means such as heat to promote condensation or other chemically driven coupling of the individual solid particles (functionalized SWNTs) to each other.

The final step in the processing drives off any excess liquid by heating to leave the final product consisting of an array of functionalized SWNTs covalently bound to another.

SWNTs fabricated according to the present invention will have a number of applications including filtration devices for water purification and physical separation, reinforced fibers and films for military applications, conductive films and paints, composites for automobile panel and airplane fuselages, membranes for batteries, hydrogen storage and biotechnology, and three dimensional composites.

The parameters of the sol gel processing may be modified to control the dimensionality and ordering in the final array. These parameters are defined as the gelation point, heat treatment temperature, concentration, degree, type and space arrangement of the functional groups on the SWNTs.

The present invention has been described with reference to the above detailed description. The true nature and scope of the present invention is to be construed with reference to the claims appended hereto.

Claims

1. A method for fabricating of macroscopic two or three dimensionally ordered arrays of single wall nanotubes (SWNTs) comprising the following steps:

chemically treating purified SWNTs using known laboratory protocols, comprised of standard organic chemistry techniques, to add chemically reactive groups to either the tube ends or tube bodies in order to functionalize the SWNTs;

suspending the functionalized SWNTs in an appropriate liquid medium such that a colloid is produced;

treating the colloid with a chemical or heat to promote coupling of the individual functionalized SWNTs to each other; and

heating the coupled SWNTs to evaporate any excess liquid so as to provide a final product comprising an array of covalently bound functionalized SWNTs.

2. A method for fabricating of macroscopic two or three dimensionally ordered arrays of single wall nanotubes (SWNTs) comprising the following steps:

chemically treating purified SWNTs using the sol gel process to add chemically reactive groups comprising alcohols or amines to either the tube ends or tube bodies in order to functionalize the SWNTs;

suspending the functionalized SWNTs in an appropriate liquid medium such that a colloid is produced;

treating the colloid with a chemical or heat to promote the covalent bonding of the individual functionalized SWNTs to each other; and

heating the coupled SWNTs to evaporate any excess liquid so as to provide a final product comprising an array of covalently bound functionalized SWNTs.

3. Performing all of the steps in claim 1 and/or 2 with addition of another substance; a polymer, epoxy, resin or ceramic material, such that the second material is added in a stable colloidal form to the colloid of carbon nanotubes, and after the steps comprising claim 1 and/or 2 are performed, a composite material is formed which consists of a two or three dimensionally ordered system consisting of carbon nanotubes and a polymer, epoxy, resin or ceramic material.

4. Utilization of a shear stress, electric and/or magnetic field on the gel produced by condensing either carbon nanotubes to themselves or carbon nanotubes to a polymer, epoxy, resin or ceramic material, such that alignment is promoted in the gel.

Abstract

A method for fabricating of macroscopic two or three dimensionally ordered arrays of single wall nanotubes (SWNTs) comprising the following steps: chemically treating purified SWNTs using the sol gel process to add chemically reactive groups to either the tube ends or tube bodies in order to functionalize the SWNTs; suspending the functionalized SWNTs in an appropriate liquid medium such that a colloid is produced; treating the colloid with a chemical or heat to promote coupling of the individual functionalized SWNTs to each other; and heating the coupled SWNTs to evaporate any excess liquid so as to provide a final product comprising an array of covalently bound functionalized SWNTs.

Figures:

Synthesis flow chart

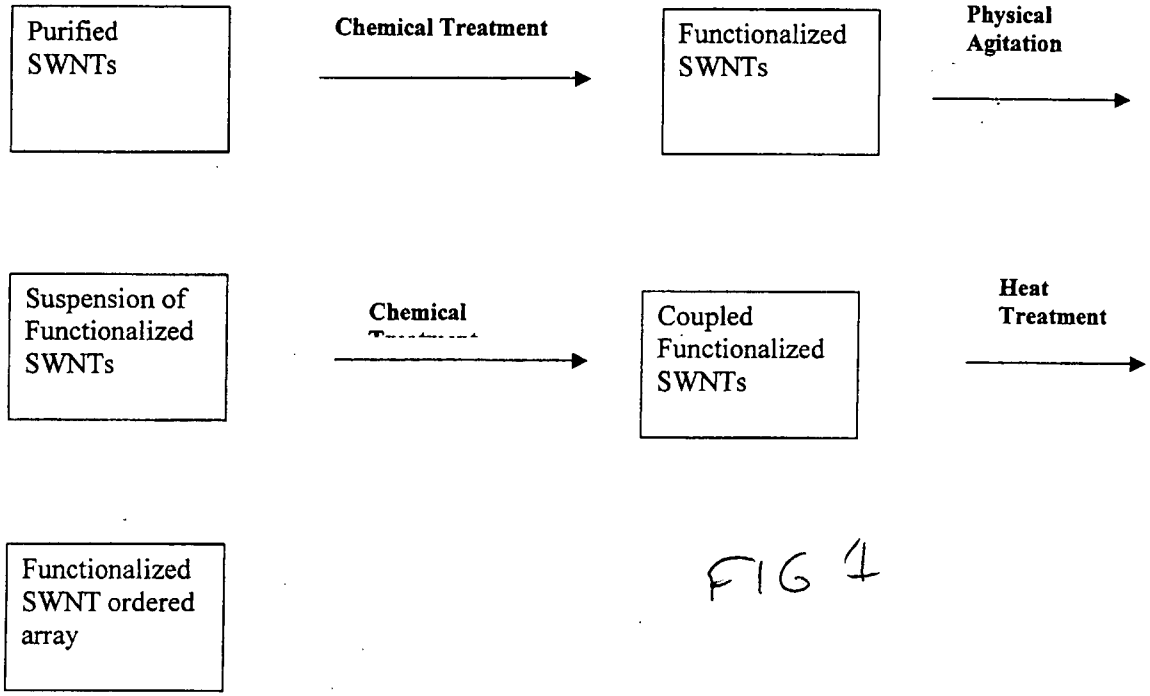
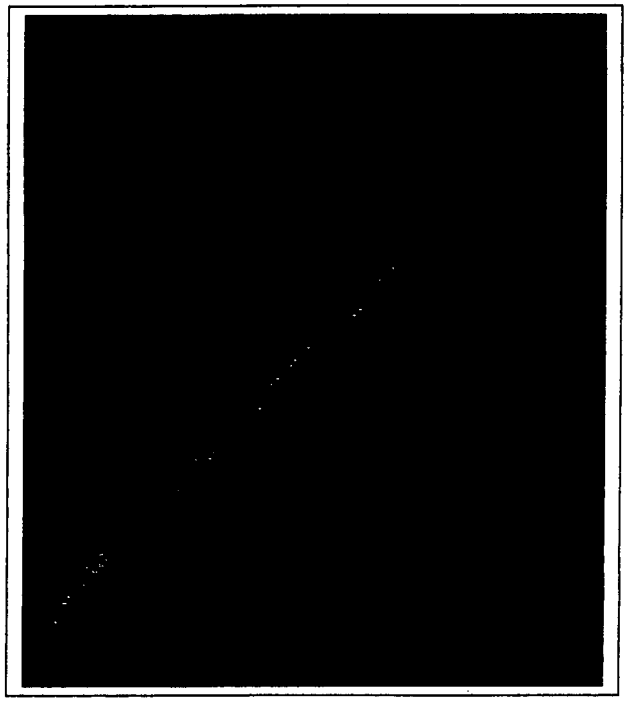


FIG 1

Computational Model of a SWNT, Daniel Colbert, Rice University



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APPLICATION NUMBER	FILING/RECEIPT DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
60/227,184	08/23/2000	Cynthia A. Kuper	65304-001

25203
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FORMALITIES LETTER

"OC000000005430595"

Date Mailed: 09/27/2000

NOTICE TO FILE MISSING PARTS OF PROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(c)

Filing Date Granted

An application number and filing date have been accorded to this provisional application. The items indicated below, however, are missing. Applicant is given TWO MONTHS from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  Applicant must submit **$ 150** *to complete the basic filing fee and/or file a small entity statement claiming such status (37 CFR 1.27).*
- To avoid abandonment, a late filing fee or oath or declaration surcharge as set forth in 37 CFR 1.16(e) of $50 for a non-small entity, must be submitted with the missing items identified in this letter.

- **The balance due by applicant is $ 200.**

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DOCKET NO: 65304-001 PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Provisional Patent Application of

Cynthia A. Kuper

Application No: 60/227,184

Filing Date: August 23, 2999

For: Method for utilizing sol-gel processing in the production of a macroscopic two or three dimensionally ordered array of single wall nanotubes (SWNTs)

I, Scott J. Fields, Registration No. 32,857 certify that this correspondence is being deposited with the U.S. Postal Service as First Class Mail in an envelope addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231 on November 27, 2000.

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Washington, D.C. 20231

RESPONSE TO NOTICE OF MISSING PARTS
OF PROVISIONAL APPLICATION

This document is hereby submitted in response to the Notice to File Missing Parts of Provisional Application.

Enclosed please find:

(1) Check in the amount of $100.00, representing payment of the filing fee and surcharge;

(2) Statement Claiming Small Entity Status of Cynthia A. Kuper; and

(3) Photocopy of the Notice to File Missing Parts of Provisional Application.

Respectfully submitted,

SCOTT J. FIELDS
Registration No. 32,857

Date: November 27, 2000

DOCKET NO.: 65304-001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Provisional Patent Application of

Cynthia A. Kuper

Application No: 60/227,184

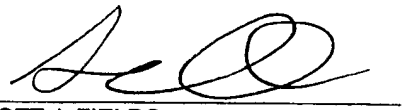
For: Method for utilizing sol-gel processing in the production of a macroscopic two or three dimensionally ordered array of single wall nanotubes (SWNTs)

Filing Date: August 23, 2000

SMALL ENTITY STATUS STATEMENT

Individual Inventor Cynthia A. Kuper claims small entity status.

Respectfully submitted,



SCOTT J. FIELDS
Registration No: 32,857

OBERMAYER REBMANN MAXWELL & HIPPEL LLP
1617 John F. Kennedy Boulevard, 19th Floor
Philadelphia, PA 19103
215-665-3214

Date: November 27, 2000

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NUMBER	FILING/RECEIPT DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
60/227,184	08/23/2000	Cynthia A. Kuper	65304-001

25203
OBERMAYER REBMANN MAXWELL & HIPPEL LLP
1617 JOHN F KENNEDY BLVD
19TH FLOOR
PHILIDELPHIA, PA 19103

FORMALITIES LETTER

OC000000005430595

Date Mailed: 09/27/2000

NOTICE TO FILE MISSING PARTS OF PROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(c)

Filing Date Granted

An application number and filing date have been accorded to this provisional application. The items indicated below, however, are missing. Applicant is given TWO MONTHS from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  Applicant must submit **$ 150** *to complete the basic filing fee and/or file a small entity statement claiming such status (37 CFR 1.27).*
- To avoid abandonment, a late filing fee or oath or declaration surcharge as set forth in 37 CFR 1.16(e) of $50 for a non-small entity, must be submitted with the missing items identified in this letter.

- **The balance due by applicant is $ 200.**

A copy of this notice MUST be returned with the reply.

Customer Service Center
Initial Patent Examination Division (703) 308-1202
PART 2 - COPY TO BE RETURNED WITH RESPONSE

12/19/2000 HHARRDL 00000021 60227184

01 FC:214 75.00 OP
02 FC:227 25.00 OP

PTO/SB/68 (08-03)
Approved for use through 7/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

REQUEST FOR ACCESS TO AN ABANDONED APPLICATION UNDER 37 CFR 1.14

Bring completed form to:
File Information Unit
Crystal Plaza Three, Room 1D01
2021 South Clark Place
Arlington, VA
Telephone: (703) 308-2733

In re Application of

Application Number	Filed
60/227184	8/23/00

Paper No. #4

I hereby request access under 37 CFR 1.14(a)(1)(iv) to the application file record of the above-identified ABANDONED application, which is identified in, or to which a benefit is claimed, in the following document (as shown in the attachment):

United States Patent Application Publication No. _____, page, _____ line _____,

United States Patent Number 6749712, column _____, line, _____ or

WIPO Pub. No._____, page _____, line _____.

Related Information about Access to Pending Applications (37 CFR 1.14):

Direct access to pending applications is not available to the public (see 37 CFR 1.14(c) if applicant) but **copies** may be available and may be purchased from the Office of Public Records upon payment of the appropriate fee (37 CFR 1.19(b)), as follows:

For **published** applications that are still pending, a member of the public may obtain a **copy** of:
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For **unpublished** applications that are still pending:

(1) If the benefit of the pending application is claimed under 35 U.S.C. 119(e), 120, 121, or 365 in another application that has: (a) issued as a U.S. patent, or (b) published as a statutory invention registration, a U.S. patent application publication, or an international patent application publication in accordance with PCT Article 21(2), a member of the public may obtain a **copy** of:
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(2) If the application is incorporated by reference or otherwise identified in a U.S. patent, a statutory invention registration, a U.S. patent application publication, or an international patent application publication in accordance with PCT Article 21(2), a member of the public may obtain a **copy** of:
the pending application as originally filed.

Signature

8/23/04
Date

RICKY OMORI
Typed or printed name

Registration Number, if applicable

703 413 0600
Telephone Number

FOR FILE INFORMATION UNIT

Approved by: _____ (Initials)
Unit: File Information Unit

POSITION	INITIALS	ID NO.	DATE
		6418	9/26/00
FEE DETERMINATION			
O.I.P.E. CLASSIFIER			
FORMALITY REVIEW			
RESPONSE FORMALITY REVIEW			

(LEFT INSIDE)